Synopsis on Low Temperature Evaluation of DC/DC Converters

Background

Electronic devices and systems for future NASA space missions must operate reliably and efficiently in extreme temperature environments. For example, inter-planetary probe launched to explore the rings of Saturn would experience a temperature of about –183 °C near the planet. These spacecraft include deep space probes, planetary orbiters and landers, and surface exploratory instrumentation. Presently, spacecraft operating in these regions utilize some kind of heating mechanisms in order to maintain an operating temperature for the on-board electronics of approximately 20 °C. The conventional heating elements used require associated containment structures and thermal systems such as shutters to maintain a temperature of 20 °C over the course of the entire mission. However, if the electronics were capable of operating at the temperature of the mission environment, these heating units and their associated structures and thermal systems could be eliminated, reducing system size and weight and thereby reducing system development and launch costs, and improving reliability and lifetime.

In addition to space missions, electronics that can operate under extreme temperatures have potential uses in terrestrial applications that include magnetic levitation transportation systems, medical diagnostics, cryogenic instrumentation, and super-conducting magnetic energy storage systems.

DC/DC Converters

Most of space and aerospace power systems are DC-based and, thus, DC/DC converters are often utilized in these systems to provide the outputs needed for different mission loads. Such outputs range from 1.5 V to 15 V at various power levels. DC/DC converters that are capable of operating at cryogenic temperatures are anticipated to play an important role in the development of microelectronics for future NASA deep space missions. Design of these converters to survive cryogenic temperatures will improve the power system performance, simplify design, and reduce development and launch costs. Recently, there has been a tremendous progress in the design of high power density DC/DC converters. When compared to standard conventional converter designs, the new converters can operate at power densities of more than 50% higher. This increase in power density was achieved by new designs, advanced devices and components, and packaging techniques. For example, the newly developed synchronous rectifier-based DC/DC converter modules with multi-layer thick film hybrid packaging provide more usable output power without the use of a heat sink than do the conventional, schottky diode based converters with a heat sink and thick-film single layer packaging. However, all of the existing DC/DC converter systems are specified to operate within a limited temperature range. Most of the commercially available devices are rated between -40 °C and + 100 °C. As a result, efforts were taken at the NASA Glenn Research Center (GRC) to investigate the performance of commercial-off-the-shelf (COTS) converters. These efforts are supported by the NASA Electronic Parts and Packaging (NEPP) Program under the Task “Mixed-Signal Devices for Low/High Temperatures”. The goal is to establish COTS performance and tolerance to extreme temperatures and to identify the temperature-induced failure mechanisms. The results of this work will expand the knowledge base on the reliability of electronic parts, and the information will be disseminated to mission planners and users groups for the design of efficient and reliable systems for space and aerospace applications.

The performance of nine commercial-off-the-shelf modular, low to medium power DC/DC converters, with specifications that might fit the requirements of specific future space missions, was investigated under cryogenic temperatures. The converters were evaluated in terms of their output regulation, efficiency, and input and output current distortions. At a given temperature, these properties were obtained at various input voltages and at different load levels; from no-load to full-load conditions. Table I lists some of the specifications of these DC/DC converters as well as a summary of their operational characteristics obtained as a function of temperature.

Table I. DC/DC converter module specifications and performance.

Converter Specifications					**GRC Evaluations**	
Manufacturer / Module	Input Voltage (V)	Output Voltage (V)	Power (W)	Operating Temp (°C)	Observations & Comments	Temp at which module ceased to operate (°C)
Astrodyne / ASD10-12S3	9 - 36	3.3	10	-40 to 60	V_{out} dropped to 2.4 V at –140 °C; chip functioned down to –160 °C.	-160
Power Trend / PT4110A	36 - 72	3.3	10	-40 to 85	V_{out} lost regulation at –100 °C; converter still functioned to –196 °C.	-196
Lambda / PM10-24S03	18 - 36	3.3	10	-40 to 70	Chip worked very well down to -120 °C. Input current oscillations occurred at all temperatures under heavy loading.	-120
Power One / DFA20E24S3.3	18 - 36	3.3	13	-40 to 85	Oscillations in input current started at –80 °C.	-120
CDI / 1003S12HN	9 - 36	3.3	10	-40 to 85	Oscillations in input current observed at –140 °C under heavy loading.	-180
Interpoint / SMHF283R3S/KR	16 - 40	3.3	15	-55 to 125	Low frequency oscillations with high peaks observed in the input current at –120 °C and below.	-160
Calex / 24S3.15HE	18 - 36	3.3	75	-40 to 100	Although the module ceased to work at –40 °C during steady state, it worked down to –100 when tested under a step change in load from full to no-load and vice-versa.	-40
SynQor / PQ48050HNA30	36 - 75	3.3	100	-40 to 115	Output voltage increased as temperature was lowered below 20 °C.	-80
Vicor / V48C12C150A	36 - 75	12	150	-20 to 100	Oscillation in input current started at –40 °C; more noticeable under heavy load conditions.	-120

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